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A Study of Characteristics of Palm Oil Biomass by Using Torrefaction Process

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ABSTRACT

This research aims to study on the impact of temperature, reaction time and particle size of biomass on the property of calorific value in 3 types of raw biomass including palm branches, balm fibres and palm shell, and to forecast the calorific value equations to study the impacts of palm branch, palm fibre and palm shell's calorific values. The experiment was carried out by grinding all raw biomass to be sized of 3 mm with a weight of 10 g each, then treated them in the reactor under the torrefaction temperature of 220 °C, 260 °C and 280 °C with a range of time at 20, 40 and 60 minutes. After that, all torrefied biomass were analyzed of their calorific values by means of ultimate analysis and proximate analysis. The study presented its result that the maximization of temperature and reaction time made the calorific value higher. The ultimate analysis showed the calorific value of palm branches is higher than the calorific value of palm shells and palm fibers showed indifferent values for both analyses. However, the proximate analysis found palm shell possessed the highest calorific value.

Keywords: Palm oil biomass; Torrefaction process; Calorific value

1. Introduction

Energy is presently playing a significant role and an important factor in driving the economy of all nations around the world, therefore, energy is essential for the national development in many areas whether it is electricity, transportation, industrial manufacturing and services, etc. However, 80 % of energy sources comes from fossil-based fuels while another 10 % is obtained from biomass. and other energy 10% [1] At present, many countries are facing the power crisis, for example, environmental pollution caused by the industrial production and the use of products obtained from fossil-based fuels. The use of

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fossil-based fuels has worsened the quality of air, soil and water, producing both direct and indirect hazards to living things and humans, many major pollutants have been tremendously formed such as air pollution which is mainly caused by the combustion of fossil-based fuels, releasing carbon dioxide and soot and subsequently followed by the global warming problem. Moreover, Sulphur compound has been also released and then formed Sulfur dioxide [2], producing acid rain by blending with rain in the air and then affecting the well-being of aquatic animals, decolorizing leaves and pausing their photosynthesis, and corroding metals and buildings. If humans extremely inhale this gas, it will cause pains and aches, anemia and harm respiratory system in human body.

In addition to pollution problems caused by the use of fossil-based fuels, at present, global resources of fossil-based fuels are almost run out due to huge global consumption because fossil-based fuels come from the remains of plants and animals that have undergone numerous changes over several millions of years due to heat and pressure in the earth's crust and formed to petroleum [3]. Many countries are aware of the effects of these issues, researchers around the world have studied and developed more alternative energies such as solar energy, wind energy, water energy as well as the trial application of biomass obtained from natural wastes, etc. Nowadays, biomass is becoming more popular to be used as fuel owing to study process, advanced technology development, local resources easily supplied and environmental conservation; more industrial manufacturing plants prefer biofuels with following reasons: local supply from community, withdrawal from high expense of import, low transportation cost and green energy when comparing to fossil fuels.

Biomass is obtained from a wide range of plants providing heat energy, the photosynthesis through the natural processes including soil, [4] sunshine, weather and water cause its physical characteristics high moisture, fragile and biodegradable. However, with the combustion process, biomass will have high quality and is suitably used as fuel, this adds its value and minimizes pollution problems. Common plants to be always use as biomass are palm, sugarcane, rice straw, rice husk, etc. Palm is considered as Thailand’s economic crop and it is generally planted in the south of Thailand, its main product is palm oil while its byproducts are palm shells, palm fiber, palm branches, palm bunches, etc. In respect of industrial sector, [5] these biomasses are applied as heating fuel for steam boilers to reduce costs and investors are also encouraged to pay attention to air pollution because biomass will emit less gas or pollutants than coal and fossils.

The combustion through torrefaction process is the pyrolysis process at temperatures typically between 200 – 300 °C, it is carried out under atmospheric pressure and in the absence of oxygen, the torrefaction process will separate water from biomass and some hemicelluloses, lignin and celluloses attain decomposition [6], converting biomass to become solid with high calorific value and low moisture absorption, and easier grind, yielding product with solid, fluid and gas forms.

Therefore, when the demand of biofuels to replace fossil-based fuels has been accelerated as the primary solution for energy shortage problem, the biomass has been tested with technology and this process is called torrefaction process, it is a thermal treatment in fixed bed reactor at low temperature between 200 – 300 °C under atmospheric pressure and in the absence of oxygen. In the experiment, wastes of palm composition which is one kind of raw biomass were tested such as palm branches, palm fibers and palm shell and its objectives are appeared below:

1. To study the impacts of temperature, particle size and reaction time on the change of biomass characteristics;
2. To study the conversion of internal compositions and elements within biomass after torrefaction process through proximate analysis and ultimate analysis.

2. Materials and Methods

In this study, the scope of study is determined as follows: raw biomass will be treated at varied temperatures ranged from 220 °C, 260 °C and 280°C, its particle size will be controlled at 3 millimeters by grinding and the experimental periods were set up at 20 min, 40 min and 60 min. Followings are raw materials and tools for research:

1.1 Raw materials: raw biomass such as palm branches, palm fibers and palm shell

1.2 Tools to be used in torrefaction process:

- Equipment used for measuring and weighing biomass consisting of ruler, flow meter, scale and stopwatch;
- Torrefaction equipment consisting of electrical heater and reactor;
- Containers for storing torrefied biomass;
- Containers for keeping samples of torrefied biomass used for the experiment;
- Drying equipment

1.3 Tools for property testing:

- Equipment used to measure calorific values consisting of bomb calorimeter, cylinder, oxygen tank and stopwatch.

From Fig. 1. Diagram showing the study procedure on biomass characteristics with torrefaction process, followings are experimental processes:

1. Starting with preparation of 3 types of raw biomass such as palm branches, palm fibers and palm shell, then grinding them and sieving them through 3-mm-size sifter;

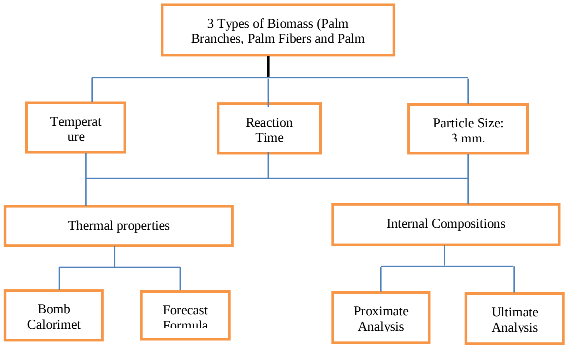

Fig. 1. Procedure study on biomass characteristics with torrefaction process

2. Drying biomass with dehydrator under the temperature at 105 °C for 24 hours;

3. Torrefaction process: weighing biomass at 10 grams each and treating them in the reactor sized 3.5 cm. x 20 cm. then input nitrogen into reactor at 100 ml / min. all the time for maintaining the condition of an inert atmosphere. The reactor will be placed in electrical heater under the temperature conditions controlled by temperature control cabinet, then the changing weight will be recorded;

4. Calculating calorific values with bomb calibrator: weighing biomass samples at approximately 1g each, then placing them at the bomb head, inserting 10-cm-long wire into small hole by sliding the cap up, after inserting both sides, sliding the cap down. Wires must not touch the edge of bomb, but need to touch on samples.

The increased temperature can be accurately calculated by equation (2.1):

$$t = t_c - t_a - r_1(b-a) - r_2(c-b) \quad (2.1)$$

Where

a Ignition time, min

b Period when the temperature reaching 60% of all increased degrees, min

c Starting time of session (after temperature is higher) which the changing temperature ratio becomes stable, min

t Accurate higher temperature, °C

t_c Starting temperature at ignition

time, °C

t_a Final temperature measured, °C

r_1 Ratio at higher temperature during 5 min. before ignition, °C/min.

r_2 Ratio at higher temperature during 5 min.after c, °C/min.

Gloss Calorific Value of Combustion can be calculated by equation (2.2)

$$Hg = \frac{tW - e_1 - e_2 - e_3}{m} \tag{2.2}$$

where

H_g Gross calorific value from combustion, J/g

W Heat capacity value of bomb calorimeter, cal/ °C

m Sample mass, g.

e_1 Amended value for the heat of HNO3 forming at 23.9, cal.

e_2 Amended value for the heat of H_2SO_4 forming at 13.7, cal.

e_3 Amended value for the heat of wire combustion (2.3 cal/cm. when using Parr 45C10 nichromefused wire)

Standard value of calorimeter can be calculated by equation (2.3)

$$W = \frac{H_m + e_1 + e_3}{t} \tag{2.3}$$

where

W Heat capacity value of bomb calorimeter, cal/ °C

H Heat of benzoic acid combustion (energizing 6318 cal/g)

m Sample mass, g

t Gross higher temperature, °C

e_1 Amended value for the heat of HNO3 forming at 23.9 cal

e_3 Amended value for the heat of wire combustion (2.3 cal /cm. when using Parr 45C10 nichrome fused wire)

5. Value analysis of carbon, hydrogen, nitrogen, sulphur, moisture, volatile matter, fixed carbon and ashes.

The equation used to predict heat values depends on the change in internal components. Forecasting (2.4) calorific value with data obtained by the proximate analysis [7] as:

$$HHV = 0.00355[C]^2 - 0.232[C] - 2.230[H] + 0.0512[CH] + 0.131[N] + 20.6 \tag{2.4}$$

Equation (2.5) forecasting calorific value with data obtained by the Ultimate Analysis [8] as:

$$HHV = 0.3536[FC] + 0.1550[VM] - 0.0078[ASH] \tag{2.5}$$

Results of proximate analysis and ultimate analysis as equation (2.6) to (2.7) can be written as follows:

Proximate Analysis:

$$VM + FC + + ASH = 100\% \tag{2.6}$$

Ultimate Analysis:

$$C + H + O + N + S + ASH + = 100\% \tag{2.7}$$

Where percentages of element existing in biomass such as Volatile Matters (VM), Fixed Carbon in Biomass (FC), Moisture (M), Ashes (ASH), Carbon (C), Hydrogen (H), Nitrogen (N), Oxygen (O) and Sulfur (S)

3. Results and Discussion

The graph of Fig. 2. and table 1 show the comparison between palm branches' calorific values measured by bomb calorimeter and calculated by equations. It is found that the value calculated by equations is slightly higher than the value measured by Bomb calorimeter. When the reaction time is longer, calorific value will be higher. After making further analysis, it is found as normalized root mean squares deviation

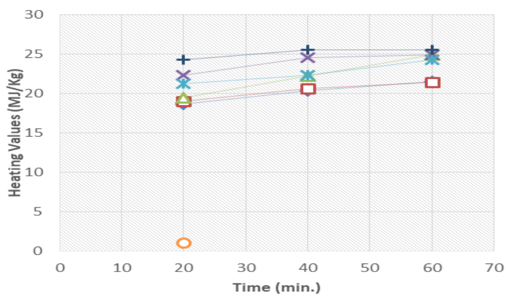

Fig. 2. Comparison between palm branches calorific values measured by bomb calorimeter and calculated by equation.

Table 1. Functions of calorific value calculation equations collected from various researches

No.	Author	Calorific Value Calculation Equations (HHV, MJ/kg)	R^2
	Proximate Analysis		
1	Jimennez and Gonzalez[16]	HHV =-10.81408+0.3133(VM+FC)	0.533
2	Sheng et al [17]	HHV =19.914-0.2324Ash	0.625
3	Demirbas [18]	HHV=0.196*FC + 14.119	-0.647
4	Demirbas [19]	HHV=0.312*FC + 0.15332*VM	-0.306
5	Cordero et al [20]	HHV=0.3543*FC + 0.1708*VM	0.247
6	Sheng et al [21]	HHV=-3.0368+0.2218VM+0.2601FC	0.617
7	M.Erol et al [22]	NHV= -116 – 1.33Ash-0.005VM+1.92(VM+Ash) -0.0227(VM+Ash) -0.0122 $(VM)^2$ + 0.0299 $(Ash)^2$ +6133(OM)-1-0.82(Ash)-1	0.898
	Ultimate Analysis		
8	Tillman [23]	HHV=0.4373C-1.6701	0.666
9	Sheng et al [24]	HHV=0.3259C+3.4597	0.758
10	Boie [25]	HHV=0.3516C+1.16225H-0.1109O+0.0628N+0.10456S	0.72
11	Graboski and Bain [26]	HHV=0.328C+1.4306H-0.0237N+0.0929S-(1-Ash/100)(40.11H/C) + 0.3466	0.647
12	Channiwala and Parikh [27]	HHV=0.3491C+1.1783H+0.1005S-0.1034O-0.0151N-0.0211Ash	0.733
13	Friedl et al [28]	HHV=3.55C2 – 232C-2230H+51.2C x H + 131N+20600	0.943
14	Demirbas [29]	HHV=0.335C+1.423H-0.0154O-0.145N	0.081
15	Jenkins [30]	HHV=-0.763+0.301C+0.525H+0.064O	0.792
16	Sheng et al [31]	HHV= - 1.3675 +0.3137C+0.7009H+0.0318O	0.834
	Chemical Composition		
17	Shafizadeh and Degr [32]	HHV=0.1739Ce + 0.2663L+0.3219E	-0.503
18	Jimennez and Gonzalez [33]	HHV=[1-Ash/(100-Ash)](0.1739Ce+ 0.2663L+0.3219)	-0.451
19	Tillman[34]	HHV= 0.1739Ce+0.2663(1-Ce)	-1.068
20	Demirbas [35]	HHV=0.0889L+16.8218	-0.875

The graph of Fig. 3. and table 1 show the comparison between palm fibers' calorific values measured by bomb calorimeter and calculated by equations. It is found that the value calculated by equations is slightly higher than the value measured by Bomb calorimeter. When the reaction time is longer, calorific value will be higher. After making further analysis, it is found as normalized root mean squares deviation.

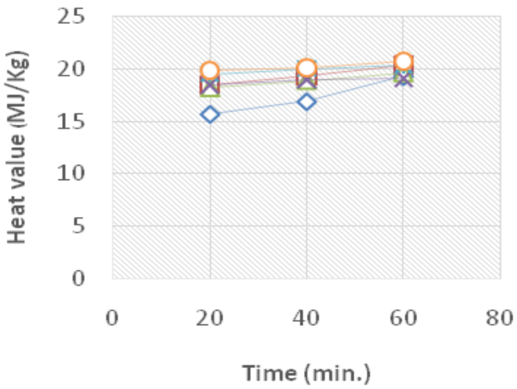

Fig.3. Comparison between palm fibers' calorific values measured by Bomb Calorimeter and calculated by equation

The graph of Fig. 4. and table 1 show the comparison between palm shells calorific values measured by Bomb calorimeter and calculated by equations. It is found that the value calculated by equations is slightly higher than the value

Measured by Bomb calorimeter. When the reaction time is longer, calorific value will be higher. After making further analysis, it is found as normalized root mean squares deviation.

From the study of biomass, the three types of recyclable energy can be obtained. Energy yield is the effect of energy per unit of weight. The effect of energy is reflected in the effect of energy be, in this study

$$y_{energy}(\%) = \left(\frac{m_{char} * HHV_{char}}{m_{biomass} * HHV_{biomass}}\right) x100 \quad (3.1)$$

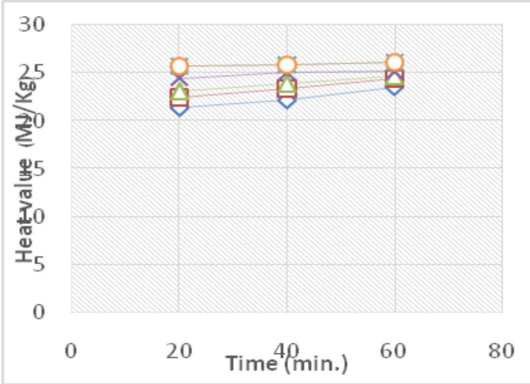

Fig. 4. Comparison between palm shells calorific values measured by Bomb Calorimeter and calculated by equations

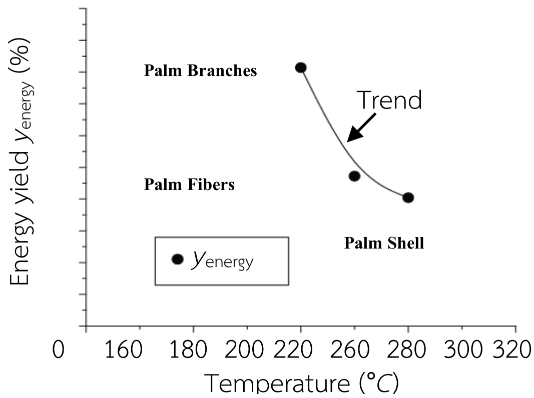

Fig. 5. Energy efficiency trends

Considering the trend of energy yield in Fig. 1, it is found that the energy gain is a significant factor at the start of the refinery reaction. But when the temperature starts to rise, the energy output starts to decrease. Significantly, the trend of the effect of shell energy is similar to the parabola graph.

4. Conclusion

The more reaction time of torrefaction, the higher calorific value shows, and found that the small size particle makes the surface of biomass. [9] Heat is generated throughout the size of cellulose particles. Hemicellulose and lignin are expelled when heat is generated. Biomass terrifier is heated at higher temperatures. [10] Due to the thermal transfer to biomass surface, temperature acts as the catalyst to make biomass heater accordingly. However, it is the normalized root mean squares deviation

When the temperature is increased and reaction time is longer, reaction time shall affect the change of calorific value the heating value, slightly maximizing calorific value, because temperature acts as the catalyst for all 3 types of biomass. It is found that when temperature is increased, ashes amount is also increased and palm fiber has the most ashes. The volatile matter (VM) is slightly reduced at the reaction time of 20 min and 40 min and palm branches have the most VM, however, Palm fibers have the most VM at the reaction time of 60 min, meaning that longer reaction time of combustion will make palm shells easier combustible. "The highest fixed carbon(FC) value of palm shell is higher due to thermal compounds,". due to thermal compounds, the more thermal compound exists, the higher calorific value was shown, respectively. It is also found that value calculated by equations shows slightly higher, [11] however, it is the normalized root mean squares deviation.

The energy yield is the effect of energy per unit of weight. The effect of energy is reflected in the effect of the energy being maintained [12] when biomass goes through the process.

The results obtained from the experiments from biomass 3 type showed that the palm gave high energy at high temperature at 200 ^{o}C. The palm fiber gave medium power at a temperature of 250 ^{o}C. Low energy palm oil. is the result of the internal components of biomass[13]. It shows that the energy value at high heat after being refined is high when the temperature rises significantly.

SUGGESTION: In order to consider and select the optimal fuel under the conditions of temperature and reaction time through torrefaction process, energy value is required to be studied because it is important to demonstrate a potential of energy and usable. Calculation of fixed value of biofuel is difficult, depending on cultivation area, moisture and plant varieties [14]. Moreover, data obtained in this study is from the experiment in laboratory, if fixed value is required, measurement of value should be continuously proceeded for further efficient use of biomass. In addition, biomass development is of higher quality. These biomass can be used to produce solid fuel [15]. To make more heat. Easy to store and move.

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